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YEAR IN CARDIOLOGY SERIES

The Year in Congenital Heart Disease

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This has been an exciting time in congenital heart disease (CHD) because more conditions are being palliated or repaired effectively and more adults are leading more active and productive lives because of their care by pediatric cardiologists and specialists in adult CHD.

Transposition of the Great Arteries (TGA) and Congenitally Corrected Transposition of the Great Arteries (CCTGA)

Koh et al. (1) report on 45 patients who underwent the double-switch. An atrial-switch plus arterial-switch procedure was performed in 7 patients, and an atrial-switch plus a Rastelli-type ventriculoarterial-switch procedure was performed in 38 patients. Early mortality was 9%. Actuarial survival at 10 years was 78%. Six patients required conduit replacement, and 2 required baffle revision. Freedom from arrhythmia was 78% at 10 years. The systemic ventricular ejection fraction was 0.57 at 1 year and 0.54 at 10 years. These procedures are options for CCTGA patients if their anatomy is reasonable and their left ventricle (LV) has not deteriorated before surgery. Patients whose ventricular septal defect (VSD) must to be enlarged are at risk for worsening ventricular function. For an infant with CCTGA and intact ventricular septum, the investigators recommend pulmonary banding at 5 or 6 months and then a double-switch procedure 6 months later.

Giardini et al. (2) used cardiac magnetic resonance in 34 patients with systemic right ventricles (RVs): 23 with atrial repair for TGA and 11 with CCTGA. The mean age was 25 years: late gadolinium enhancement (LGE) was present in 41% of cases and was associated with older age, lower right ventricular ejection fraction, higher wall stress, reduced oxygen uptake, and arrhythmia. Twelve patients had worsening of their condition associated with decreases in biventricular function and increases in the prevalence of LGE. Cardiac magnetic resonance can be useful in following up patients with systemic RVs, particularly when considering double-switch versus transplantation when function deteriorates.

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Fratz et al. (3) present data showing that myocardial scars are not common in systemic RVs. These investigators studied 18 patients with TGA after atrial-switch and 9 CCTGA patients without surgery. Only 1 patient had an LGE scar; positron emission tomography showed no scars. One reason for the difference between these studies and previous ones is that these patients underwent surgery at a younger age and had less time for development of scars before surgery. They suggest that some of the previous studies had overzealous interpretation of abnormal perfusion or LGE. Another possibility is that their patients were younger, and only 2 of 9 CCTGA patients and 4 of 18 TGA patients had an ejection fraction $<40\%$. There is progressive deterioration of RV function, which might be related to abnormal scars in patients with systemic RVs; most show minimal deterioration of function in their 20s but progressive deterioration with increasing age, particularly in the 4th to 6th decades.

Lange et al. (4) reported on 417 TGA patients after atrial-switch surgery. Survival was 76% for the Mustard operation and 91% for the Senning procedure at 25 years. Patients in the Mustard group died more often from arrhythmia than patients in the Senning group and needed more baffle reoperations. A VSD closure at the time of operation and the Mustard operation were independent risk factors for late mortality; 86% of the patients led a normal life with full-time work, and 12% did part-time work. This represents the "glass half full" for atrial-switch procedure patients rather than "half empty." Although the results look reasonably good, RV dysfunction was present in 16% at 25-year follow-up. The Senning procedure was performed at a time when myocardial protection was probably considerably better than with the Mustard procedure. Finally, systemic RV dysfunction is more likely to happen in the 4th or 5th decade than in the 2nd or 3rd decade. Nevertheless, this report is encouraging, and hopefully these patients will continue to lead active and productive lives with current management strategies.

Rouine-Rapp et al. (5) studied 29 neonates undergoing an arterial-switch procedure to determine whether segmental wall motion abnormalities indicate myocardial ischemia. Intraoperative transesophageal echocardiography readings were recorded at baseline and after bypass. The transthoracic echocardiography readings were obtained before discharge. Segmental wall motion was normal in 9 neonates

and abnormal in 20 early postbypass. Abnormalities were persistent at chest closure in 15 of 20 neonates. There was electrocardiographic evidence of ischemia in 2 of 9 with normal wall motion, 1 of 5 with transient wall motion abnormalities, and 9 of 13 with wall motion abnormalities at chest closure. Troponin levels at 12, 24, and 48 h and intraoperative segmental wall motion abnormalities were predictive of postoperative abnormalities. There were no deaths. Most of these patients do well despite transfer of coronary vessels with significant intraoperative ischemia of ≥1 h. The fact that more of them do not have segmental wall motion abnormalities can be attributed to the surgical skills of our colleagues and improved myocardial protection. It is important to follow up these patients to determine whether wall motion abnormalities persist and whether they are associated with structural or functional coronary abnormalities, arrhythmia, and/or ventricular dysfunction.

Losay et al. (6) reported on aortic regurgitation (AR) after arterial switch for TGA in 1,156 hospital survivors. At 76 months, 15% had AR. Complex TGA, prior pulmonary banding, arch anomalies, AR at discharge, older age at switch, and aortic/pulmonary size discrepancy were associated with AR. Freedom from AR was 70% at 15 years. Reoperation for AR was performed in 16 patients with 1 death. Freedom from reoperation for AR was 97% at 15 years and slowly increased from 2 years to 16 years. Aortic regurgitation is uncommon in terms of significant volume overload. Unfortunately, it is present in some and may require late surgery.

Bautista-Hernandez et al. (7) reported on aortic root translocation plus arterial switch for TGA with LV outflow obstruction in 11 children ages 1 month to 11 years. The aortic root was excised and inserted in the LV outflow tract, enlarging it by resecting the outlet septum and putting in a patch. After coronary reimplantation, RV outflow reconstruction was achieved with a homograft (see Figs. 1 to 4 in Bautista-Hernandez et al. [7]). There were no deaths with follow-up of 59 months; 5 patients required 6 conduit replacements at a median of 53 months. Two patients required implantable defibrillators, and none have developed LV outflow obstruction. The investigators advocate this approach when the pulmonary valve is dysplastic or even bicuspid, the pulmonary annulus is abnormally small, unresectable pulmonary stenosis is present, and/or a straddling tricuspid valve is associated with a small RV. It requires a long cross-clamp time but can be useful in the conditions indicated. It could become the procedure of choice for TGA and LV obstruction if it can be performed with equal or improved morbidity and mortality as the standard Rastelli procedure.

Tetralogy of Fallot (TF)

Chong et al. (8) reported on aortic root dilation in 67 children after repair of TF. Aortic dilation defined as a *z*-score >2 was found in 88% at the annulus and 87% at the sinus. Duration of follow-up was the only determinant of dilation; AR was present in 12% of patients who had larger dimensions at all aortic levels. These patients had increased aortic stiffness and reduced strain and distensibility. A TF repair was performed at 3 years on average, and despite relatively early correction, the cases show progressive aortic dilation. I have considered aortic dilation after TF repair to be caused by the large right-to-left shunting occurring over many years before repair. Dilation can continue after repair despite having right-to-left shunting with high systemic output for a relatively short period of time preoperatively. This may program the aorta for progressive dilation. Fortunately, severe aortic root dilation and AR are uncommon with childhood repair, and aortic aneurysm with dissection has not been reported to my knowledge.

Laudito et al. (9) reported on 112 patients younger than 6 months of age who underwent repair of TF or truncus, with an atrial septal defect (ASD) left in 80. In patients with an ASD, mean oxygen saturation reached a nadir of 94% and mean arterial pO_2 a nadir of 73 mm Hg at 16 to 24 h; both increased during the second 24 h. At hospital discharge, median saturation was 98% (range 86% to 100%). Mean right atrial pressure was >10 mm Hg in 30 patients and was associated with older age and transannular patch. Clinically significant desaturations were rare. Infants <2 months of age are at higher risk for desaturation. Leaving an interatrial communication to provide a "pop-off" if RV pressure and/or distensibility is increased after TF repair has been done for many years. Occasionally, patients will have desaturation significantly early, or on occasion, late postoperatively with changes in RV diastolic properties and/or progressive pulmonary regurgitation. These investigators state that if the patent foramen ovale was larger than 4 to 5 mm, it was partially closed to 4 to 5 mm. The question remains regarding which patients require this for a smooth postoperative course. Having to go back and close these defects with an interatrial device is relatively easy now, but I would hope that it could be avoided in the majority of patients if one could come up with an algorithm for when to leave a small ASD.

Airan et al. (10) reported on 860 patients ages 6 months to 40 years undergoing correction of TF, with 334 considered suitable for transatrial repair. Perioperatively, 30 patients required right ventriculotomy and transannular patch and were excluded. In addition, pulmonary arteriotomy was required in 71 patients. There were 4 hospital deaths and 4 early reoperations for residual/additional VSD in 3 and tricuspid regurgitation in 1. Two patients had complete heart block. Echocardiography at discharge showed a peak RV outflow gradient of 20 mm Hg and was reduced to 13 mm Hg after an interval of 19 months. In 300 cases (90%), feasibility of transatrial repair could be predicted accurately. Patients were referred at a later age and only 10% of these patients had a prior shunt, indicating that these were not the severe TF patient needing infant surgery. Contraindications

to this procedure are the need for pulmonary root enlargement or pulmonary arterioplasty.

Bockeria et al. (11) report on TF repair with unilateral absence of the left pulmonary artery in 25 and the right in 2 patients. Twenty patients underwent palliative procedures including aortic root pulmonary shunts, transluminal pulmonary valvuloplasty, and reconstructive RV outflow tract without VSD closure. At a median of 3.6 years after palliation, 13 patients underwent complete repair and 7 had primary repair. Mortality after palliation was 1 in 20 or 5%, and mortality after repair was also 1 in 20 or 5%. These investigators suggest that a Nakata index >200 mm^2/m^2 and z-score >-4 are criteria for successful repair. If the index is less, these patients should have palliation before repair. This is a rare condition, and obviously one hopes that a diagnosis can be made early in life and that the pulmonary artery, which may be isolated with a ductus, can be salvaged so that repair to both lungs can be performed.

Amark et al. (12) report on factors associated with mortality, reintervention, and achievement of complete repair in TF with pulmonary atresia. Of 220 children presenting to their institution, a total of 185 underwent surgery and repair was definitive in 75%. Initial procedures were systemic pulmonary artery shunts in 57%, complete primary repair in 31%, and RV outflow tract reconstruction in 12%. Based on angiography, 118 patients had simple pulmonary atresia and 53 had major aortopulmonary collateral vessels. Survival from the initial procedure was 71% at 10 years. Risk factors for death after this procedure included younger age, earlier birth cohort, and fewer bronchopulmonary segments supplied by native pulmonary arteries and initial placement of a systemic pulmonary artery shunt. Competing risk analysis for initially palliated patients predicted after 10 years that 68% achieved complete repair, 22% died without repair, and 10% remained alive without repair. Reoperations after repair occurred in 27%, with risk factors including older age at palliation, major aortopulmonary collateral arteries, and more segments supplied by collateral vessels. Outcome improved with time and was better in completely repaired cases. The difficult patients in this group are those with major aortopulmonary collateral arteries, of which there were 53. Of these, 24 were dead after no intervention, without reaching repair or after staged repair. The push for an early primary procedure or at least RV outflow tract reconstruction for those whose central pulmonary arteries are small or absent continues to be the treatment of choice for many centers. Hopefully this group of patients will continue to show improved outcome with the new techniques as emphasized by Reddy et al. (13).

Hypoplastic Left Heart

Ghanayem et al. (14) reported on randomization to either the RV–pulmonary artery conduit or a Blalock-Taussig (BT) shunt as initial palliation of hypoplastic left heart syndrome (HLHS) patients. There were 1 early and 1 late death in the conduit group and 1 interstage death in the shunt group. Diastolic blood pressure was lower in the shunt group, but there were no differences in arterial saturation, venous oximetry, mean blood pressure, and pulmonary/systemic flow ratio between groups. These 2 types of palliation for the first stage of HLHS palliation are associated with similar results by experienced teams. There is a randomized study being performed with a larger number of patients, and hopefully it will answer more definitively the question of whether one type of palliation has a more favorable outcome in different HLHS subtypes. These investigators believe that the use of phenoxybenzamine is important for afterload reduction in both the conduit and the shunt procedures.

Jaquiss et al. (15) reported on early superior cavopulmonary anastomosis (SCPA) after stage I procedure in 85 patients with HLHS. Patients were divided into group 1 with SCPA at 4 months (33 patients), and group 2 with SCPA at >4 months (52 patients). Sixty-nine patients have undergone Fontan procedures, 7 await Fontan procedures, 1 underwent transplantation, 3 are not Fontan candidates, and 5 died late. Group 1 and group 2 patients who had a completed Fontan procedure were compared for preoperative and postoperative variables. There are no differences in these variables or late functional assessment, and actuarial survival at 6 years was not different. Although initially more cyanotic and hospitalized longer, younger SCPA patients achieved clinical equivalence for the Fontan procedure and afterward. These data support performance of early SCPA to try and prevent interstage mortality.

Li et al. (16) reported on the adverse effects of dopamine on systemic hemodynamic status and oxygen transport in HLHS after the Norwood procedure. Systemic oxygen consumption was continuously measured in 13 sedated, paralyzed, and mechanically ventilated neonates for 72 h after the Norwood procedure. Terminating dopamine was not associated with changes in arterial pressure, Qp/Qs, or oxygen delivery. Dopamine induces increasing VO_2 in neonates after the Norwood procedure; termination is associated with improved VO_2 and oxygen transport balance. These data emphasize the need for cautious management in the use of inotropes, particularly dopamine, in these fragile infants.

Gruber et al. (17) reported results of single-stage biventricular repair of severe aortic hypoplasia or atresia in 21 infants with VSD and normal LV. Aortic atresia was present in 7 patients, aortic stenosis in 14 patients, and 6 patients had interrupted arch. All patients with aortic stenosis had annular diameters 3 mm or smaller. Circulatory arrest time was 55 min; cross-clamp time was 56 min. In-hospital survival was 100%, with 1 late death. There was no significant outflow tract obstruction; total stay was 17 days. Reoperation was necessary in 10 cases, with leaks in the VSD baffle common. The ASD was downsized to 2 to 4 mm in all patients.

This is an outstanding result in this patient group; noncardiac anomaly or genetic syndrome did not contribute to mortality or morbidity.

Fontan

Meyer et al. (18) report on outcomes of the Fontan procedure using cardiopulmonary bypass with aortic cross-clamping in 160 patients with a mean age of 2.2 years; HLHS was present in 71% and heterotaxy in 12%. Aortic cross-clamping was used in 96% and deep hypothermic circulatory arrest in 83%. A lateral tunnel Fontan was used in 43% and an extracardiac Fontan in 57%: fenestration was used in 90%. Freedom from death or take-down was 98%. Median duration of pleural drainage was 2 days. Median duration of hospitalization was 6 days (range 3 to 55 days). Some investigators have suggested that the management strategy should be to avoid bypass and cross-clamping in these patients to prevent the consequences of bypass and perioperative myocardial dysfunction. The Fontan procedure completed the old-fashioned way can be performed with outstanding results.

Giannico et al. (19) report on the clinical outcomes of 193 extracardiac Fontan patients. There were 165 of 193 early survivors who underwent noninvasive follow-up and at least 1 catheterization. The overall survival was 85% at 15 years. Freedom from late failure among hospital survivors was 92% at 15 years. The incidence of late major problems was 24%; 11% had arrhythmias, 3% had obstruction of conduit, 3.5% had left pulmonary artery stenosis, and 3% experienced ventricular failure leading to heart transplantation in 3 of 5. Protein-losing enteropathy was found in 2 patients, and 4 patients died late, 2 after transplantation. Functional status and cardiopulmonary performance was excellent. The incidence of late death, obstructions of the cavopulmonary pathway, is lower than that reported after other Fontan operations, although follow-up is not as prolonged. Obstruction of the conduit remains a potential long-term problem. There were 36 patients with more than 10 years of follow-up, and conduit obstruction developed in only 5. The mechanism of obstruction was longitudinal torsion during rapid growth. Cardiac magnetic resonance data showed no decreasing diameter after 6 months. This is good news if it can be repeated in other patients; the conduit story has not been so happy when used in other situations.

Fiore et al. (20) report on a comparison of lateral tunnel with extracardiac conduit in 162 patients, 49 extracardiac conduit and 113 lateral tunnel. Extracardiac conduit patients were older and had a higher frequency of heterotaxy syndrome, and lateral tunnel a higher frequency of HLHS. Preoperative saturation, rhythm, diastolic pressures, and transpulmonary gradient were similar. Cardiopulmonary bypass was similar, but fewer extracardiac conduit patients needed aortic cross-clamping. Fenestrations were more frequent in lateral tunnel cases, 73% versus 16%. Operative mortality was 1.8% overall and not different between groups. In addition, there were no differences in transpulmonary gradient, readmission for effusion, and changes in ejection fraction relative to preoperative level. Resource use was higher in the extracardiac group; loss of sinus rhythm and frequency of all neurological events did not differ. There were 7 late deaths equally distributed between groups. Actuarial survival at 5 years was not different; 90% for extracardiac, 95% for lateral tunnel patients. It seems that you can do quite well with either operation. As one of the discussants says, "it is best to tailor the operation to patient and not try to tailor the patient to the operation."

Tatum et al. (21) report on pulmonary artery growth after Fontan procedure. Sixty-one children who underwent a modified Fontan procedure at a median age of 53 months and had angiography for assessment of pulmonary size before and during follow-up were studied. An atriopulmonary connection was present in 23 patients, and total cavopulmonary connection was present in 38 patients. Postoperative angiograms were performed at a median of 19 months after Fontan procedure. The growth of each artery was measured just before the first branching point. The growth of pulmonary arteries failed to match the increase in body surface area in the majority of patients. It is speculated that poor pulmonary artery growth may be a factor in late Fontan procedure failure. Hopefully most patients in the first 3 to 4 months before their bidirectional cavopulmonary anastomosis will have enough antegrade flow or shunt flow to give them adequate-sized pulmonary arteries so that this will be less of a long-term factor. Patients with large pulmonary arteries tend to sail through their Fontan procedure with good midterm results.

Senzaki et al. (22) report on 17 Fontan procedure patients with good functional status and 20 patients with normal 2-ventricle circulation serving as a control group in whom they examine changes in contractility, diastolic function, and loading factors at rest, with atrial pacing and beta-adrenergic stimulation. At baseline, Fontan procedure patients showed minimum abnormalities of cardiac properties, but an increase in afterload resulted in decreased cardiac index. In addition, Fontan circulation was associated with limited inotropic response and worsening of diastolic filling with increased heart rate leading to decreased systolic pressure and elevation of central venous pressure. Furthermore, beta-adrenergic reserve was markedly decreased in patients owing to limited preload reserve. These studies show abnormalities that have been associated with exercise in adults with congestive heart failure. Improvements in prognosis after Fontan procedure may require development of medical interventions that can overcome limitations that are inherent in the Fontan circulation.

Backer et al. (23) reported on results of conversion of the failed Fontan circulation in 78 patients and transplantation in 8 patients because of failure of the Fontan circuit, with 4 of 8 having failed attempted conversion. Surgical techniques consist of excision of the dilated right atrium, arrhythmic surgeries, 24-mm extracardiac conduit placed at the inferior

caval vein to the pulmonary arteries, bidirectional SCPA, and epicardial pacemaker. There were 1 early and 3 late deaths. In addition, the investigators highlight previous studies indicating an overall early mortality of 2% and late mortality of 4% for this procedure. For cardiac transplantation, 60-day mortality is 27%. Obviously transplantation patients were much more symptomatic. One of the most challenging aspects of dealing with a failing Fontan procedure is when to go for conversion and when to go to transplantation.

Bernstein et al. (24) report on the outcome of listing for cardiac transplantation for failed Fontan procedure with a multi-institutional review of 97 Fontan procedure patients <18 years of age. The mean age at listing was 9.7 years, with 25% <4 years. Pretransplantation survival was 78% at 6 months and 74% at 12 months, and was similar to that for 243 children with other congenital heart disease (CHD) and 747 children without CHD. At 6 months the probability for receiving a transplant was similar for status 1 and 2; however, the probability of death was higher for status 1 (22% vs. 5%). Seventy patients underwent transplantation, and survival was 76% at 1 year and 68% at 5 years, slightly less than CHD and no CHD patients. The cause of death included infection in 30%, graft failure in 17%, rejection in 13%, sudden death in 13%, and graft coronary artery disease in 9%. Protein-losing enteropathy resolved in all 34 who survived >30 days. Heart transplantation is an effective therapy for pediatric patients with a failed Fontan procedure, midterm results are encouraging, and protein-losing enteropathy can be expected to resolve. This represents excellent continued palliation for those patients who have failed the last stage repair for their single-ventricle malformation.

Valvular Disease

Ruzmetov et al. (25) presented data on 147 patients ages 10 days to 18 years who underwent aortic valve replacement. Overall, early and late mortality was 7.5%, and survival was estimated at 93% at 20 years. Date of procedure was a risk factor for death, and follow-up was completed in 136. Valve-related reoperation rate was 20%. Reoperation rate was highest in the xenograft group, followed by mechanical valves, homograft, and the Ross procedure. Ross procedure patients show significant increases in aortic annulus and sinus diameter at last follow-up. The potential for development of significant autograft insufficiency and ascending aortic aneurysmal dilatation is small but warrants annual follow-up. These investigators support the Ross procedure as the procedure of choice for children. Patients who have progressive dilation of the aortic root and require reoperation represent a challenging surgical procedure. Fortunately, these patients are rare and usually are those with severe AR before surgery. Whether or not the pulmonary root in these patients (who most likely had bicuspid aortic valves) are structurally similar and prone to progressive dilatation is unclear.

Reemtsen et al. (26) reviewed 16 neonates with profound heart failure caused by the Ebstein anomaly. Indications for surgery were overt heart failure, cyanosis, and acidosis associated with tricuspid regurgitation, depressed RV function, and severe cardiomegaly. The strategy was first to assess the possibility for repair with or without RV outflow tract reconstruction. If this was not feasible, RV exclusion was performed by oversewing the tricuspid valve with a patch. A reduction atrioplasty was performed, and depending on the extent of the atrialized portion of the RV, plication was performed. A modified BT shunt provided pulmonary flow. The univentricular approach evolved to include a fenestration in the tricuspid valve patch to allow for RV decompression. Tricuspid valve repair was undertaken in 3 patients, with 1 requiring conversion to RV exclusion 3 months after the initial operation. In those with RV exclusion, the tricuspid patch was fenestrated in 10 of 13. One patient had heart transplantation as the initial procedure. There were 5 hospital deaths and no late deaths. Survival of the cohort with a fenestrated tricuspid valve patch was 80%, versus 33% for the nonfenestrated group. Surgeries including homograft placement in the RV outflow tract, whether during repair or during RV exclusion, ended in death. These investigators conclude that RV exclusion with a fenestrated tricuspid valve patch, reduction right atrioplasty, plus a BT shunt have provided effective palliation for neonates presenting with critical Ebstein anomaly and a valve that cannot be repaired.

It is frequently difficult to decide whether or not a 2-ventricle repair is feasible. If the patient has a tripartite RV with open RV outflow tract, the investigators attempt to repair the valve; otherwise they would go to RV exclusion. They also make it clear that they attempt to stabilize these patients and not to perform surgery on neonates.

Guleserian et al. (27) reported on the natural history of 32 patients with pulmonary atresia with intact ventricular septum and RV-dependant coronary circulation managed by the single-ventricle approach. All underwent initial palliation with a modified BT shunt. The median tricuspid valve z-score was -3.62, and all had moderate or severe RV hypoplasia. The median follow-up was 5 years, and mortality was 19%, with all deaths occurring within 3 months of shunting. Aortocoronary atresia was associated with 100% mortality in 3 patients. Of the survivors, 19 have undergone a Fontan procedure, whereas 7 have received a bidirectional Glenn shunt, awaiting a Fontan procedure. Actuarial survival was 81% at 15 years. No late mortality occurred among those surviving beyond 3 months. These patients' early mortality seems related to coronary ischemia at the time of BT shunt. Those with aortocoronary atresia should undergo transplantation. It is sometimes difficult to determine whether the patient is entirely dependant on RV pressure for coronary circulation. These investigators defined it by either the presence of ventriculocoronary fistulae with angiographically severe obstruction of 2 major coronary arteries, complete coronary atresia, or situations in which a

significant portion of LV was supplied by the RV and was judged at risk for ischemia with RV decompression or clinical deterioration with ischemia on RV decompression. During bypass, the RV must be kept filled, or there will be reduced coronary perfusion with ventricular dysfunction. They used cardiopulmonary bypass at the time of bidirectional Glenn and Fontan procedures with adequate RV filling and contraction maintained. They do not use cardiopulmonary bypass during shunt construction.

Beroukhim et al. (28) reported on the progression of aortic dilation in 101 children with isolated bicuspid aortic valve and no hypertension, or any syndrome, and compared data with 97 control patients. Mean age was 9 years, and was not different between patients and control patients. Patients had larger aortic dimensions in all regions of the aorta, with the most striking discrepancy in the ascending aorta. The size discrepancy was present from birth and persisted throughout childhood. Patients had significantly greater increases in ascending aorta dimension than control patients per year of follow-up. Bicuspid aortic valve is complicated by progressive aortic dilation beginning in childhood.

Beroukhim et al. (29) also studied patients with isolated bicuspid aortic valve compared with patients with Marfan syndrome. Patients with bicuspid valve had greater dilation than those with Marfan syndrome at the ascending aorta, with dilation often extending cranially beyond the region of measurement. Conversely, patients with Marfan syndrome had more focal dilation at the sinuses of Valsalva compared with control patients. This difference in patterns of dilation is important in terms of the measurements that are obtained. Surgical recommendations for the Marfan group may not be applicable to the bicuspid valve group given the different sites and degrees of dilation. Although aneurysmal dilation of the ascending aorta certainly occurs with isolated bicuspid aortic valve, dissection and/or rupture is rare given the almost 1% prevalence of the anomaly in the population.

Ciotti et al. (30) compared 117 patients with bicuspid aortic valves and 62 patients with bicuspid valves plus coarctation. The median age of patients with bicuspid aortic valve was 4 years, and with coarctation was 1.9 years. Bicuspid aortic valves with right/left cusp fusion were significantly associated with coarctation and cardiac anomalies, whereas valves with noncoronary/right cusp fusion were affected by valvular dysfunction. Compared with normal tricuspid valves, bicuspid valves had aortic root dilation, even in children with no hemodynamic disturbance. The difference is still significant comparing bicuspid and tricuspid valves with coarctation. Although detectable early in life, valvar dysfunction and aortic root dilation progress with age.

Canna et al. (31) reported on adults with ascending aortic dilation with normally functioning bicuspid and tricuspid aortic valves. These investigators performed transesophageal echocardiography >12 months apart in 113 patients, with 27 having bicuspid valves and 86 having tricuspid valves with aortic diameters of 40 to 60 mm and no significant aortic stenosis or AR. Diameters of the sinuses of Valsalva, the sinotubular junction, and the tubular tract were similar in both groups. During 3-year follow-up, the rate of ascending aorta diameter progression was similar for the bicuspid and tricuspid valve groups. Three patients in the tricuspid valve group experienced cardiac death, 2 died suddenly, and 1 died after surgery for aortic dissection. There was no occurrence of cardiac death in the bicuspid valve group. In conclusion, the rate of progression of ascending aortic aneurysms was similar in patients with bicuspid valves versus those with tricuspid valves. Furthermore, patients with bicuspid valves did not have increased rates of aneurysm-related complications compared with patients with tricuspid valves. After reading all 4 of these studies, several things seem to be clear: children with bicuspid aortic valves have larger aortas in the ascending area than patients with tricuspid valves, even without associated defects or hypertension. The progression of the dilation in young patients seems to be greater in bicuspid valves than with other groups. Patients with coarctation have a particular type of bicuspid valve and are prone to dilation. Ascending aortic aneurysms with rupture are exceedingly rare, but when an adult has an aortic root that is significantly dilated, it will progress at the same rate as those with tricuspid aortic valves and not at a greater rate.

It is still unclear what to do with the asymptomatic patient whose aortic root is dilated to 5 cm. Certainly, with any valvular surgery that is needed, aortic root replacement or some type of procedure to try to protect against future aneurysmal dilation and dissection should be performed. If patients do not have hypertension, the conservative approach may be useful, but patients should be followed up closely and any rapid progression in dilation or questionable symptoms should be a signal for consideration for root replacement. Cardiac magnetic resonance studies can be helpful in this regard.

Interventional Catheterization

Szkutnik et al. (32) reported on the use of the Amplatzer muscular VSD occluder (AGA Medical Corp., Golden Valley, Minnesota) for closure of perimembranous VSDs in 10 patients, ages 3.2 to 40 years. These VSDs had a mean diameter of 5.4 mm with extension toward the muscular septum; mean distance from the aortic valve was 5.4 mm in all but 1 patient. All procedures except 1 were performed without complication, and complete closure was achieved. One patient had a residual shunt with hemolysis, which resolved after 10 days. Trivial tricuspid regurgitation appeared after the procedure in 3 patients. No other complications were observed in follow-up from 0.2 to 3.5 years. These investigators resorted to a muscular VSD occluder in these patients because of previous problems with heart block using the asymmetric septal occluder, which was designed for the perimembranous VSD. One wonders why the

majority of these small VSDs were closed: 7 had VSDs 4.5 mm or less and cannot have had significant LV volume overload at the ages reported. In most centers, these cases would not have been sent for surgery or for interventional closure.

In an accompanying editorial by Sullivan (33), there is an excellent review of VSD closure. Interventional closure of perimembranous VSD is rarely performed in the United Kingdom currently, and the suggestion is that all patients be submitted to a registry when this is done. The incidence of heart block in one registry in Europe is 5% or 13 of 250 undergoing closure of perimembranous VSD; 4 of these were transient but 9 were permanent, occurring late after VSD closure in 4 of these patients. Sullivan also reports that at the Great Ormond Street Hospital, incidence of complete heart block occurring after surgical closure of VSDs was 7 of 996 patients (0.7%). In summary, small VSDs do not warrant closure with a device when there is no LV volume overload or other indication for surgical closure such as a prolapsing aortic valve cusp. In addition, patients who are having perimembranous VSDs closed with a device should be reported to a registry so that accurate data can be obtained and the risks and benefits known.

Mullen et al. (34) reported a prospective, multicenter study of 58 patients ages 28 years to 68 years with a clinically significant ASD or patent foramen ovale who had percutaneous shunt closure with a new bioabsorbable ASD implant. Successful implantation was achieved in 98% (57 of 58 patients). Closure at 30 days and 6 months was 92% and 96%, respectively. There was no evidence of a clinically significant response to the device. Transient atrial arrhythmia occurred in 5 patients after implantation. No major safety issues were observed. This is a novel implant designed to provide biological closure of atrial-level defects using the natural healing response; 90% to 95% of the implant is absorbed and replaced with native tissue, and future access to the left atrium may be achieved when needed. This is a potentially outstanding breakthrough.

Aggarwal et al. (35) reported on 28 of 31 patients who underwent stent placement for palliation of RV pulmonary artery conduit stenosis. The RV/systemic pressure ratio decreased from 0.75 to 0.52, and conduit diameter increased from 9 to 12 mm in one view and 8 to 12 mm in the orthogonal view. In patients with successful placement, 29% were free from a second intervention. In the remaining patients, the median time to reintervention was 16 months (range 6 to 44 months). Second interventions were successful in 8 of 13 patients. Complications included balloon rupture in 4, stent fracture in 2, and pseudoaneurysm formation in 1. If there is a coronary vessel crossing the RV outflow tract, one must do test balloon dilation to be sure coronary ischemia does not occur before stent placement. Conduits continue to be problematic, and stent palliation may be useful in patients before surgery.

Coats et al. (36) reported on relief of RV outflow tract obstruction in 18 patients with percutaneous valve implantation. All had a gradient >50 mm Hg without important pulmonary regurgitation. The RV gradient decreased from 51 to 22 mm Hg, and RV pressure from 73 to 47 mm Hg. Exercise capacity improved, as did RV and LV ejection fraction. This more physiological treatment of conduit obstruction is hopeful in terms of palliation. How long it will last and whether it will be difficult to remove surgically in the future remain unclear.

Agnoletti et al. (37) reported on 15 patients with right-to-left ASD shunt after repair of complex conditions. Percutaneous ASD closure was performed with exercise tests before and after. Five patients were cyanotic at rest, and during exercise saturations ranged from 94% to 84%. The ASD closure led to an increase in saturation from 94% to 99%, and at 3 years, all but 1 patient with a residual ASD had normal saturations during exercise. Maximum workload increased from 7 to 9 metabolic equivalents. These defects can be troublesome long-term, and some patients develop enough cyanosis to limit their exercise capacity. In such patients, device closure seems reasonable.

Tzifa et al. (38) reported on use of covered stents for coarctation as a rescue treatment in patients with aneurysm or previous stent-related complications and patients at risk for developing complications because of complex anatomy or advanced age. Thirty-three stents were implanted in 30 patients (range 8 to 65 years); 16 patients had previous procedures. The systolic gradient decreased from 36 to 4 mm Hg after the procedure, and the diameter of coarctation increased from 6 to 17 mm. The follow-up period was 40 months (mean 11 months). All stents were patent and in good position on computed tomography or cardiac magnetic resonance imaging 3 to 6 months later. In 43%, antihypertensive medication was decreased or stopped (see Figs. 1 to 3 in Tzifa et al. [37]). This is a good rescue treatment for patients with complicated anatomy or previous aneurysms. Hopefully it can be shown to have significant longevity.

Carr (39) reports on a review of endovascular stenting and angioplasty versus surgery for adult coarctation. The immediate improvements in hypertension and the morbidity were similar across groups. Surgery was associated with a low risk of restenosis or recurrence, whereas endovascular therapy had a higher incidence of restenosis and repeat intervention. This is an interesting report from a surgeon. It should be clear that this review is not comparing apples to apples. To have a true comparison, the complexity of coarctation and previous complicating features would have to be similar in the 2 groups. Nevertheless, this is interesting reading, and perhaps there will be a review by interventionalists in the future. When considering therapy for an adult with coarctation or recoarctation, the details of the anatomy and the skill and experience of both the surgeon and interventionalists must be considered in terms of management.

Ou et al. (40) reported on the effect on blood pressure of aortic shape deformation after coarctation surgery. They studied normotensive patients with repair by simple or extended end-to-end anastomosis. All patients had exercise

studies and cardiac magnetic resonance imaging. Three types of aortic arch geometry were evident: Gothic arch with angular geometry and an increased height-to-width ratio in the arch, Crenel arch with a rectangular arch shape, and normal arch with a smooth rounded shape. Exercise-induced hypertension was more frequent in patients with Gothic arch, with a prevalence of 83% at 15 years after surgical intervention versus 25% in those with Crenel and 21% of those with normal arch geometry. The cumulative incidence of exercise-induced hypertension was higher in patients with Gothic arch through follow-up. This provocative study shows why some patients who have normal blood pressure differences between arms and legs at rest and no anatomical narrowing of any significance on cardiac magnetic resonance angiography develop hypertensive upper-extremity blood pressure with exercise. Whether this type of architecture can be avoided with certain surgical modification is unclear, but hopefully there will be innovative surgeons who will find ways to improve the architecture.

Adult CHD

Marelli et al. (41) studied the prevalence of CHD in Quebec, Canada, where each individual is assigned an identification number by age 1 year. The prevalence of CHD was determined in 1985, 1990, 1995, and 2000. Children were defined as <18 years of age and adults as ≥18 years old. The prevalence was 4.09 per 1,000 adults in the year 2000 and 0.38 per 1,000 for those with severe lesions. The median age of all patients with severe CHD was 11 years in 1985 and 17 years in 2000. The prevalence of severe CHD increased from 1985 to 2000, but the increase in adults was higher than in children. In the year 2000, 49% of those with severe CHD were adults. This study indicates the changing of the guard in terms of the number of patients with CHD. Adult patients outnumber pediatric patients, and more and more adult specialists will need to be taking over their care each year as more specialists are trained to do so.

Rossano et al. (42) retrospectively reviewed patients ≥18 years old who underwent cardiac surgery at a pediatric institution. There were 149 operations in 135 patients, with 2 early deaths. There were 70 preoperative noncardiac morbidities in 49 patients, and 140 preoperative cardiac morbidities in 78 patients. Preoperative arrhythmia and moderate to greater systolic dysfunction were most common. There were 51 postoperative adverse noncardiac events in 32 patients. Renal insufficiency was most common. There were 53 postoperative adverse cardiac events in 44 patients, ventricular tachycardia in 13 patients being most common. Risk factors for adverse postoperative noncardiac events included preoperative histories of New York Heart Association functional class III or greater and psychiatric disorder. Risk factors for postoperative adverse cardiac events included older patient age, preoperative functional single ventricle, New York Heart Association functional class III or greater, and atrial fibrillation/flutter and ventricular tachycardia or fibrillation. Postoperative adverse events occurred frequently when adults undergo cardiac operations. Many patients with complex congenital cardiac conditions are now best served at children's hospitals because of the expertise of the surgeon, intensive care unit, and CHD team of specialists. Adult problems that are not familiar to pediatric specialists will occur in many of these patients, and their postoperative care eventually will be best served by those with both pediatric and adult training in CHD and with expertise in adult cardiac and noncardiac disease. This again emphasizes the need for development of adult cardiologists with special experience and expertise in CHD.

Genetic Issues

Colan et al. (43) reported on prospective and retrospective data of children diagnosed with hypertrophic cardiomyopathy (HCM). Of 855 patients <18 years old with HCM, 8.7% had inborn errors of metabolism, 9.0% had malformation syndromes, 7.5% had neuromuscular disorders, and 74% had idiopathic HCM. Children with HCM associated with inborn errors of metabolism and malformation syndromes have significantly worse survival. Patients with idiopathic HCM diagnosed before 1 year of age had worse survival from the time of diagnosis than those diagnosed after 1 year of age. Patients with idiopathic HCM who survive to at least 1 year of age have an annual mortality rate of 1% regardless of whether they were diagnosed before or after 1 year of age. Patients presenting before 1 year of age have the broadest spectrum of causes and the poorest outcomes. The annual mortality rate of 1% for children is much lower than previously reported in children and is not different from adults. These data are useful in caring for pediatric and young adult patients with HCM. Risk management and stratification of patient therapy including ICD use remains a difficult task.

Arnestad et al. (44) reported on the prevalence of long QT syndrome gene variants in sudden infant death syndrome. Mutations and rare variants were found in 26 of 201 cases or 13%. On the basis of their functional effect, the investigators considered that 8 mutations and 7 rare variants found in 19 of 201 cases likely contributed to 9.5% of deaths. Sudden arrhythmic death is an important contributor to sudden infant death syndrome.

Miscellaneous

Cheung et al. (45) reported on a randomized, controlled trial of the effects of remote ischemic preconditioning in children undergoing cardiac surgery. Thirty-seven patients were studied, with 20 control patients and 17 patients in the investigational group. Bypass and cross-clamp times were not different. Levels of troponin I postoperatively were greater in the control patients than in the preconditioned group, and inotropic requirement also was greater in control patients at 3 and 6 h. This study shows the myocardial

protective effects of ischemic preconditioning using a simple, noninvasive technique of 5-min cycles of lower limb ischemia and reperfusion. These novel data support the need for a larger study of remote ischemic preconditioning.

Mildh et al. (46) reported on cardiac troponin T levels for risk stratification in pediatric heart surgery. Data were obtained on 1,001 children over the course of 5 years. Level of troponin T >5.9 mg/l on the first postoperative day predicted death (odds ratio 10.7), as did admission lactate level >5.2. No other variables had any independent effect on 30-day survival. Troponin T level on the first postoperative day is a powerful risk marker of death. This measurement can be used to stratify patients and emphasizes the need for improved myocardial protection techniques during surgery.

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